OBSERVATIONS ON THE ADULT ALEWIFE'S FOOD HABITS (PISCES: CLUPEIDAE: *ALOSA PSEUDOHARENGUS*) IN INDIANA'S WATERS OF LAKE MICHIGAN IN 1970[1, 2]

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RHODES, RAYMOND J. AND THOMAS S. MCCOMISH. Observations on the Adult Alewife's Food Habits (Pisces: Clupeidae: *Alosa pseudoharengus*) in Indiana's Waters of Lake Michigan in 1970. Ohio J. Sci. 75(1): 50, 1975.

Adult alewives, *Alosa pseudoharengus* (Wilson) collected from June to October 1970, at a 10-m deep station in Lake Michigan near Michigan City, were examined for stomach contents. Zooplankton (cladocerans and copepods) comprised the largest volume of stomach contents in two alewife size groups (140–169 mm and 170–189 mm) in all months except June. In June larval aquatic insects (chironomids) comprised the highest volume of identifiable food items. Only a slight difference in the average percent volume and presence of food items occurred when comparing the two groups. In pooled samples of alewives (149–189 mm), the percent occurrence and volume of cladocerans in stomachs generally increased from June to October. Maximum copepod percent volume occurred in July followed by a decline to least percent volume in October. *Pontoporeia affinis* was an abundant October food item, and immature chironomids attained maximums in June.

In addition to other factors (e.g., lamprey predation, water quality changes, etc.) the landlocked alewife, *Alosa pseudoharengus* (Wilson), has influenced the stocks of numerous Lake Michigan fish species. Smith (1970) suggested that alewife competition for food, space and other resources may be partially responsible for the decline of the following Great Lake fish species: emerald shiners (*Notropis atherinoides*), lake herring (*Coregonus artedii*), American smelt (*Osmerus mordax*) and yellow perch (*Perca flavescens*). Wells & McLain (1972) feel that the alewife has been detrimental to native fish stocks probably due to competition with young for planktonic food, or by actual predation on the young. The alewife has also been implicated by Wells (1970) as the cause of decreased abundance, smaller body size and smaller size at onset of maturity in several zooplankton species.

The objective of this investigation was to examine food habits of adult alewives after spring migration into shallow Indiana waters of southern Lake Michigan. Although Norden (1968), Morsell and Norden (1968) and Gannon (1972) examined aspects of the food habits of the Lake Michigan alewife, none of their samples were from Indiana waters. An accurate assessment of alewife food habits in all regions of Lake Michigan is essential to an understanding of alewife inter- and intraspecific competition.

METHODS AND PROCEDURES

Alewives were sampled at a 10 m deep station approximately 1.7 km northeast of the Michigan City Harbor lighthouse. Sampling equipment consisted of 76.0 x 1.8 m nylon experimental gill nets having five 15.2 m panels of stretch mesh of the following dimensions: 3.8, 5.1, 6.4, 7.6 and 10.2 cm. Gill nets were usually set on the bottom.

Samples were collected at 6- or 7-hour intervals (0600, 1200, 1800, 2400 hr) during 24 hour periods from June to September. Samples were also collected after a 24 hour period during June, September and October (table 1). Processing of fish was usually initiated within 15 minutes after collection. The entire digestive track was removed, wrapped in cheesecloth, labeled and preserved in 10% formalin. The alewife's total length in millimeters was taken with the caudal fin depressed.

The stomach and esophagus was cut open, and the contents flushed into vials. Only contents in the stomach and esophagus, hereafter referred to as stomach, were examined because preliminary examinations of duodenal contents usually revealed organisms in an advanced stage of digestion. Quantification of stomach contents was derived, and the entire contents of each stomach were classified into identifiable or unidentifiable material by the author. Contents of individual vials were poured into separate Petri dishes, and insect larvae and large zooplankters (e.g., *Leptodora kindtii*) were

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TABLE 1
Alewife collected in Lake Michigan at 10 meters depth in 1970.

Date	Size groups (mm)				# collected
	120–139	140–169	170–189	190+	
June 8	0	6	9	2	17
June 9–10*	0	33	61	15	109
June 11	0	1	0	5	6
July 7–8*	0	35	26	1	62
July 23–24*	0	6	25	2	33
August 11–12*	0	25	7	0	32
September 8–9*	0	46	7	0	53
September 12	1	12	1	1	15
October 22	2	14	14	1	31
TOTAL	3	178	150	27	358

*Sampling 24-hr period.

identified and enumerated at 10×. The remaining contents were washed into a graduated cylinder and diluted to volumes of 20 or 50 ml depending upon zooplankton abundance. A 1 ml sub-sample was removed from the thoroughly-mixed contents of the graduated cylinder with a Hansen-Stempel pipet and transferred to a Sedewick-Rafter counting cell. All organisms in the sub-sample were identified and enumerated using strip counts at 40× with a binocular microscope.

Volumes of food items in the stomach were determined by measuring zooplankton with a calibrated ocular micrometer, assigning a geometric figure approximating that species' shape, and computing the mean volume as described by McComish (1967). In stomachs with the contents classified as unidentifiable, the volume of contents was estimated in graduated centrifuge tubes after centrifugation for five minutes at about 2000 rpm. The volume of individual items in each stomach was calculated from the numerical abundance or organisms and added to the centrifuged volume of unidentifiable material for an estimate of total stomach volume. The mean volume of stomach items for a given alewife size group and sampling month was then calculated by dividing the estimated total stomach volume for a given food item by the number of stomachs with contents.

Data presented by Johnson (1972) was used for comparing stomach contents and zooplankton abundance. Johnson took vertical plankton tows at 5, 10, 15, and 18 m near the Michigan City station using a 1.5 m long modified Wisconsin plankton net with a mouth opening of 24.5 cm and constructed of No. 20 silk bolting cloth. Plankton samples were usually collected within three days of fish collection periods, and three 1 ml sub-samples were taken from each plankton sample. Zooplankton in the sub-samples were identified, enumerated, and the mean number of zooplankters in the three sub-samples was calculated.

RESULTS

Effects of Fish Size on Food Habits. Most fish collected were 140–190 mm long (table 1), so analyses of stomach contents were performed only on fish in this size range. These fish approximated Norden's (1967) age groups II (140–169 mm) and III (170–189 mm). Of 328 stomachs examined, 209 were empty.

A comparison of the two size groups revealed only slight differences in the mean percent volume and occurrence of zooplankton in stomachs (table 2). The

TABLE 2
Stomach contents of alewives in size groups 140–169 millimeters collected at 10 meters depth in Lake Michigan.

Food item	Size group (mm)			
	140–169		170–189	
	V	O	V	O
Zooplankton	63	77	57	83
Cladocera	43	72	34	76
Copepoda	20	68	23	71
Malacostraca	6	15	5	14
Ostracoda	*	*	*	*
Insecta (Chironomids)	9	13	10	29
Hirudinea	3	2	6	2
Hydracarina	*	1	*	2
Unidentifiable**	19	19	22	15
Stomachs with food	65		54	
Empty stomachs	113		96	
Empty stomach %	63.5		64.0	

* Less than one per cent. V=mean % volume; O=% frequency of occurrence.
**Material in an advanced state of digestion.

TABLE 3
Stomach contents of alewives 140–189 millimeters collected each month at 10 meters depth in Lake Michigan.

Food item	Date									
	June		July		August**		September		October	
	V	O	V	O	V	O	V	O	V	O
Zooplankton	28	74	53	59	68	71	93	96	72	100
Cladocera	2	46	16	53	45	71	71	96	65	100
Copepoda	26	74	37	48	23	57	22	96	7	50
Malacostraca	*	3			*	14	1	6	22	50
Ostracoda	*	3					1	1		
Insecta	35	54	1	11			*	10	6	17
Hirudinea			21	8						
Hydracarina	*	8					*	3		
Unidentifiable***	37	26	25	33	32	29	5	6		
Stomach with food	39		27		7		40		6	
Empty stomachs	71		65		25		26		22	
Empty stomach %	64.5		70.6		78.1		39.4		78.6	

* Less than one %. V = mean % volume; O = % frequency of occurrence.
** 140–169 mm fish only.
***Material in an advanced state of digestion.

cladoceran volume of 43% in the 140–169 mm group was slightly greater than the 34% of the 170–189 mm group. Cladoceran frequency of occurrence for the same groups was 72% and 76% respectively. Copepod percent volume and occurrence were similar for the two size groups. The copepod volume for fish in the 140–169 mm group was 20% while that for the 170–189 mm group was 23%. Copepod occurrence in the two respective size groups was 68% and 71%.

The percent volume and occurrence of malacostracans were similar for the two size groups (table 2). Malacostracans, mainly *Pontoporeia affinis*, occurred in 15% of the 140–169 mm fish, and in 14% of the 170–189 mm fish and comprised volumes of 6% and 5% in the two respective groups. Malacostracans appeared to be an incidental food except in October, when they comprised 22% of the volume and occurred in 50% of the stomachs. A difference of only one percent in volume of insects occurred between the two major size groups. However the 29% difference of insects in the 170–189 mm group was more than twice the 13% occurrence in the 140–169 mm group. Differences in occurrence of insects for the two size groups were related to season. Stomachs of 170–189 mm alewives in June generally contained more larval chironomids than the 140–169 mm group. In addition, stomachs of the 170–189 mm group from October contained chironomids, but none were found in the 140–169 mm fish.

Monthly Changes in Food Habits. Alewives in size groups 140–169 mm and 170–189 mm were combined for a monthly analysis of food habits. The small sample size in both August and October probably excludes any firm conclusions on the alewife's diet during these months. Zooplankton volume in stomachs generally increased through the sampling period with a low of 28% in June and a high of 93% in September, followed apparently by a slight decline in October to 72% (table 3). Occurrence of zooplankton ranged from a low in July of 59% to an apparent maximum in October of 100%.

The seasonal pattern of cladoceran volumes in stomachs was similar to that described for zooplankton; a low in June of 2%, a peak in September of 71% (table 3). Cladoceran occurrence in stomachs attained a minimum of 46% in June. Both *Chydorus sphaericus* and

Bosmina longirostris were present in stomachs at maximum percent volume and frequency of occurrence in September (table 4). *Leptodora kindtii* contributed the largest amount (38%) to the cladoceran volume in October. *Daphnia retrocurva* and *Bosmina coregoni* were present in 100% and 83% respectively of the alewife stomachs in October. Regardless of month, *Cyclops bicuspidatus* was the major copepod consumed (table 4). The maximum copepod volume, 37%, occurred in July alewife stomachs. The copepod volume ranged between 22% and 26% during the other summer months including September. Occurrence of copepods reached a high of 96% in September.

DISCUSSION

During the summer sampling Morsell (1968) attributed the high percent of empty stomachs in Lake Michigan alewives to the influence of spawning behavior because Norden (1967) reported that spawning of the Lake Michigan alewife extends from June to August with a peak in July. In contrast, Edsall (1964) found no alewives with empty stomachs out of 60 specimens he captured with a minnow seine during spawning activities. In our investigation the sampling gear may have increased the occurrence of empty stomachs, because it is not uncommon for fish to regurgitate some or all of their stomach contents when caught in a gill net. Other factors like the alewife's feeding chronology and digestion rate probably contributed to the high percentages of empty stomachs.

In addition to the high occurrence of empty stomachs, unidentifiable material (usually decomposed crustacean fragments) also hampered this investigation. Gannon (1972) has reported that Lake Michigan cladoceran and copepod species become unrecognizable sooner (within 3.5 hrs. at 15° C ambient water temperature) than larger macrobenthos (e.g. chironomids) when consumed by the landlocked alewife. Gannon's results suggest that zooplankton food items could be underrepresented relative to macrobenthic food items.

TABLE 4

Zooplankton stomach contents of alewives 140–189 millimeters collected at 10 meters depth in Lake Michigan.

Food Item	Date									
	June		July		August**		September		October	
	V	O	V	O	V	O	V	O	V	O
Zooplankton	28	74	53	59	68	71	93	96	72	100
Cladocera	2	46	16	53	45	71	71	96	65	100
Bosmina coregoni							*	29	13	83
Bosmina longirostris	*	46	10	51	9	57	26	89		
Ceriodaphnia lacustris							*	4	*	17
Chydorus sphaericus	*	8	*	28	2	29	13	92		
Daphnia retrocurva	*	8	*	3	2	43	6	69	14	100
Diaphanosoma brachyurum			*	5			*	36		
Eurycerus lamellatus	1	5	*	5	19	29	24	49		
Holopedium gibberum			5	14	13	14	*	1		
Leptodora kindtii							1	22	38	100
Polyphemus pediculus			*	5			*	1		
Copepoda	26	74	37	48	23	57	22	96	7	50
Calanoid copepodites	*	13	*	3	1	14	*	36		
Cyclopoid copepdites	2	64	*	44	*	43	1	90	*	17
Cyclops bicuspidatus	22	74	35	48	16	17	16	96	5	50
Diaptomus spp.	*	8	*	9			*	39		
Epischura lacustris							4	18	1	33
Eurytemora affinis			1	16	6	57	1	47	1	50
Harpactacoida	1	26	*	5			*	1	*	17

*Less than one %. V = mean % volume; O = % frequency of occurrence.
**140–169 mm fish only.

It seems questionable whether the captured alewives were feeding in the immediate vicinity of the plankton samples reported by Johnson (1972), since Webb (1973) has shown that the Lake Michigan alewife undergoes major diurnal movements between 18 m and 5 m (or less) during the summer months. Other than discussing the monthly zooplankton abundance between 18 m and 5 m compared to alewife food items, quantification of the alewife's food electivity does not seem justifiable due to the alewife's diurnal movements and previously mentioned problems.

Within the limitations of sampling methods, there was generally a small difference in the food habits of alewives in 140–169 mm and 170–189 mm size groups captured at the 10 m sample station in Indiana waters. Zooplankton was the most important food of both groups. Alewife food habit studies in other lakes have shown that microcrustaceans (mainly cladocerans and copepods) usually comprise the highest frequency of occurrence in the alewife diet (e.g. Price, 1963; Lackey, 1969; and Hutchinson, 1971). Results of this investigation also showed that during the sampling months from June to October zooplankton (cladocerans and copepods) comprised the largest volume and occurrence in alewife stomachs.

Morsell and Norden (1968) found that the same size groups of alewives in Wisconsin waters of Lake Michigan captured at 10 to 30 m showed differences in zooplankton contents. In Wisconsin waters the 140–169 mm group zooplankton made up about 30% (dry weight) of the stomach contents, while in the 170–189 mm fish group, zooplankton only comprised about 11%. Morsell and Norden (1968) stated that on an annual basis *P. affinis* was probably the most important item in the alewife's diet in Wisconsin waters. However, Wells (1970) suggested that *P. affinis* was second to zooplankton in importance as a food item for Lake Michigan alewives. Morsell and Norden (1968) conceded possible bias in their food habit analysis due to the use of a bottom trawl for collection of fish, but Wells (1968a) points out that alewives tend toward a bottom existence as they mature. Besides annual changes in the availability of *P. affinis*, the question of benthic or limnetic feeding by alewives is complicated by the vertical migration of *P. affinis* (Wells, 1968b).

Bosmina longirostris was not observed in October stomach samples, but it was present in October plankton tows taken at the fish collection site and in samples from water up to 18 m in depth (Johnson, 1972). *B. coregoni*, however, was present in peak numbers in both October plankton tows (Johnson, 1972) and alewife stomach samples. Brooks (1969) has suggested that the alewife would prefer *B. coregoni* to *B. longirostris* due to greater visible size. Indeed, *B. coregoni* in Johnson's plankton samples were usually larger in size than *B. longirostris* (personal observation).

In the early 1950's when the alewife was not common in Lake Michigan (Smith, 1968), *Leptodora kindtii* reached its maximum density in the summer months (Wells, 1960). Near Michigan City *L. kindtii* was present in peak numbers in October plankton tows during 1970 (Johnson, 1972). Due to the alewife's migration into deeper water after mid-September (Wells, 1968a), the October population highs of *L. kindtii* and *B. coregoni* may be related to the alewife's reduced inshore density. During summer months when alewives were abundant in Indiana waters, size dependent predation by alewives may have influenced these zooplankters' abundance.

Cyclops bicuspidatus was the major copepod species consumed by alewives during the summer months at the Indiana sample site. Morsell and Norden (1968) reported *C. bicuspidatus* as a major zooplankter in the diet of alewives during the summer months in fish sampled from 10 to 30 m in Wisconsin waters. According to Wells (1960), *C. bicuspidatus* is a very common copepod in Lake Michigan and exhibits population peaks in June and July. Johnson (1972) reported the 1970 population peak of *C. bicuspidatus* in Lake Michigan near Michigan City, Indiana occurred in August. Since the peak percent volume of this species in stomachs occurred in July, prey selectivity may be related more to prey size than abundance.

Insects, primarily chironomid larvae, were a significant item in the alewife diet only during June at the Indiana sample site. Morsell and Norden (1968) observed that the highest occurrence of chironomids consumed by alewives in Wisconsin waters (nearly 82%) was in July. Other investigators also observed insects in the diet of alewives during the summer. In Echo Lake, Maine, the volume of insects in alewife stomachs in June, July and August was 24%, 28%, and 30% respectively (Lackey, 1969). Hutchinson (1971) also found various species of insects in alewife stomachs during the summer, although they did not represent a major portion of the diet.

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